U.S. ARMY COMBAT CAPABILITIES DEVELOPMENT COMMAND

Hydrogen Fuel Cell Technology and Its Military Applications

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Fuel Cell Technologies, Ground Vehicle Power & Mobility

Ground Vehicle Systems Center

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GROUND VEHICLE SYSTEMS CENTER FUEL CELL TECHNOLOGIES TEAM

Fuel Cell Technologies Team's Mission

- Explore and evaluate fuel cell power generation technologies and their support equipment that enable tactical advantages for ground vehicle systems.

Fuel Cell Technologies Team Overview

- Recent and Ongoing projects
  - Solid Oxide Fuel Cell (SOFC) + JP-8 Reformation Auxiliary Power Unit
  - Fuel Cell All Terrain Transport (FCATT, Hydrogen based)
  - General Motors Colorado ZH2 & SURUS
  - Tactical Hydrogen Operational Refueler (THOR) and JP-8 reformation systems
  - GM Hydrogen Ecosystem (Silverado ZH2 + Hydrogen Generation Capability)

- Expertise focused on SYSTEM level development, test, and demonstration. Some limited independent research and development at lowest levels.

DISCLAIMER

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CCDC GVSC ZH2 Fuel Cell Vehicle: Military User Assessments

PURPOSE: Obtain soldier feedback within an operational context demonstrating the capabilities of a hydrogen fuel cell powered vehicle. Use Data and Soldier feedback to shape follow-on fuel cell vehicle efforts.

Eglin, AFB: May 2017

- AFSOC Medics
- 6th Rangers (RTB)
- 7th Special Forces Group

Ft. Carson: June 2017

- 4th Infantry Division
- 10th Special Forces Group

Ft. Bragg: August 2017

- 82nd Airborne Division
- 3rd Special Forces Group

Ft. Benning / MCoE: Sept 2017

- 75th Ranger Regiment
- 316 Cav
- MCoE/MRD/Maneuver Warfighter Conference

5-Day Evaluation Concept

- Day 1 - Soldier Training, Familiarization and Safety
- Day 2 - Soldier Driven Mobility
- Day 3 - Power Generation, Static Display
- Day 4 - Soldier Driven Reconnaissance
- Day 5 - VIP/Media/Sr. Leader Ride and Drives/Display

Other Evaluations:

- Performance Confirmation Testing
- Signature
- H2 tank initial small arms
- Marine Corps
- 25th ID
- NSW

COLORADO ZH2 VIDEO

SILENT MOBILITY, SILENT WATCH, & EXPORTABLE POWER

Extended Silent Watch
Provides 2.5 kw of export power
For 24 hours on 4kg of H2
(~4gal JP-8 equivalent)

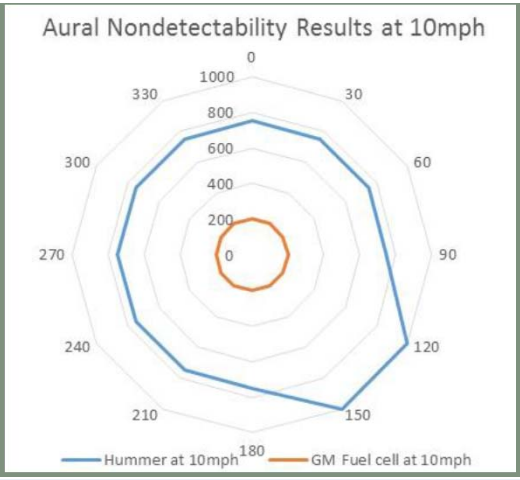
ZH2 in its Undetected Distance from Objective during Night Ops

"If we can creep up on the enemy and can do it stealthily in our vehicle, we can accomplish our mission more efficiently."

"We can get closer into enemy territory undetected, making our vehicle weapons and call for support more lethal."

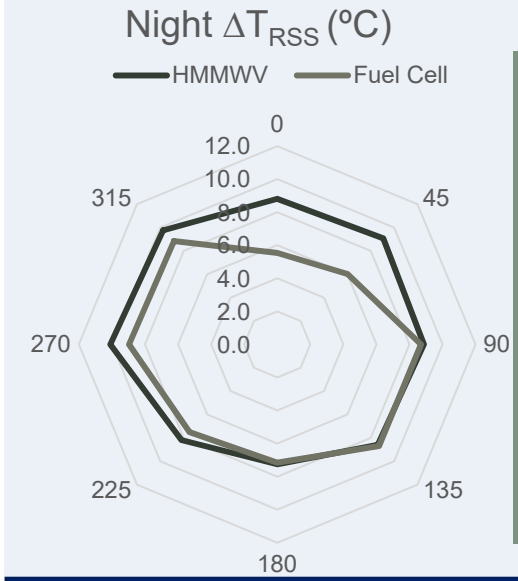
Fuel Cells Enable Silent Mobility and Extended Silent Watch

SIGNATURE MANAGEMENT: ACOUSTIC AND THERMAL BENEFITS



By comparing two like vehicle systems (Colorado ZH2 & HMMWV) the fuel cell vehicle has a 75-90% improvement for its acoustic signature.

With an integrated approach, 100m non-detectability at 10mph is achievable



The use of fuel cells and electric drive shows promise to lowering thermal signatures but must be part of an integrated signature design

"If we can get within a 100 meters of the enemy undetected, we take away their ability to call in for airstrike and artillery support" by CPT Traitses 4th ID

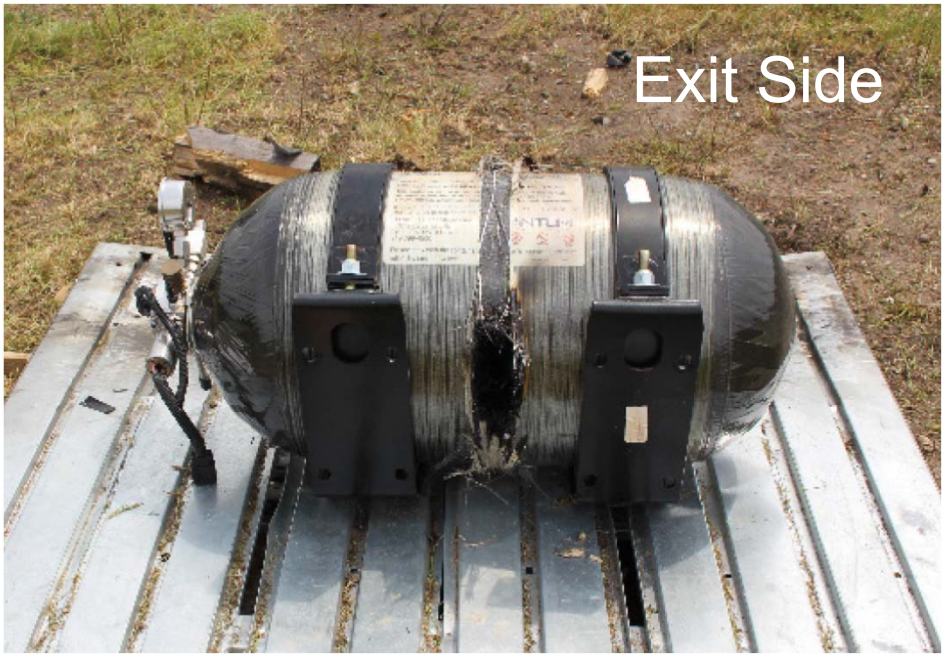
BALLISTIC TESTING OF COMPRESSED HYDROGEN

7.62 API test after impact: (a) the initial flame jet after penetration along with visible exit plume, (b) flame jet sustained briefly while particulates burn off and transitions to a near-invisible hydrogen flame, (c) small flame from a residual particle passing through the near-invisible hydrogen flame.

BALLISTIC TESTING OF COMPRESSED HYDROGEN

Cylinder before RPG test

BALLISTIC TESTING OF COMPRESSED HYDROGEN



Cylinder after RPG test

US ARMY APPLICATIONS

Army vehicles are heavy and energy-intensive

Main Battle Tank (M1A2 SEPV3)
Weight: >66 tons
➔Est. >250 kg H2

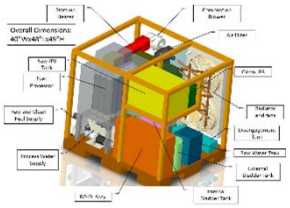
Off-Road Heavy Transport (HEMMT, M977…)
Weight: >35 tons
➔Est. >80 kg H2

Family of Medium Tactical Vehicles (M1078…)
Weight: >14 tons
➔Est. >35 kg H2

Joint Light Tactical Vehicle
Weight: >7.5 tons
➔Est. >25 kg H2

Over 30 Platforms weighing up to 100 tons
Approximate “extra space” onboard = None
Preferred weight change = reduction in weight
Acceptable range change = Increase only

HYDROGEN GENERATION OPTIONS (VIABLE SUPPORT)

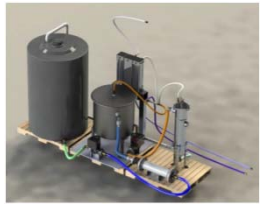


Multi-Fuel Reformer

- Use when other fuels are widely available in a region
- Best choice for reforming on the move

Benefits

- Produce a common fuel from multiple sources
- Reduce fuel transportation by using local resources



Aluminum Powder

- Only requires a water source

Benefits

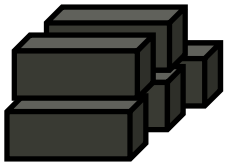
- Reduce logistics through reuse of waste products
- Can use gray and/or salt water

Electrolysis

- Use when access to electrical infrastructure or renewables is available

Benefits

- Reduce logistics through reuse of waste water
- Mature, commercially available



Solid State Hydrogen

- Use when increased range and energy dense storage is required

Benefits

- Can be transported with dry cargo
- Requires no capital investment in hardware

Multiple options for hydrogen generation based on the operational scenario and available local resources

ARMY LOGISTICS IMPACT WITH HYDROGEN FUEL CELL VEHICLES

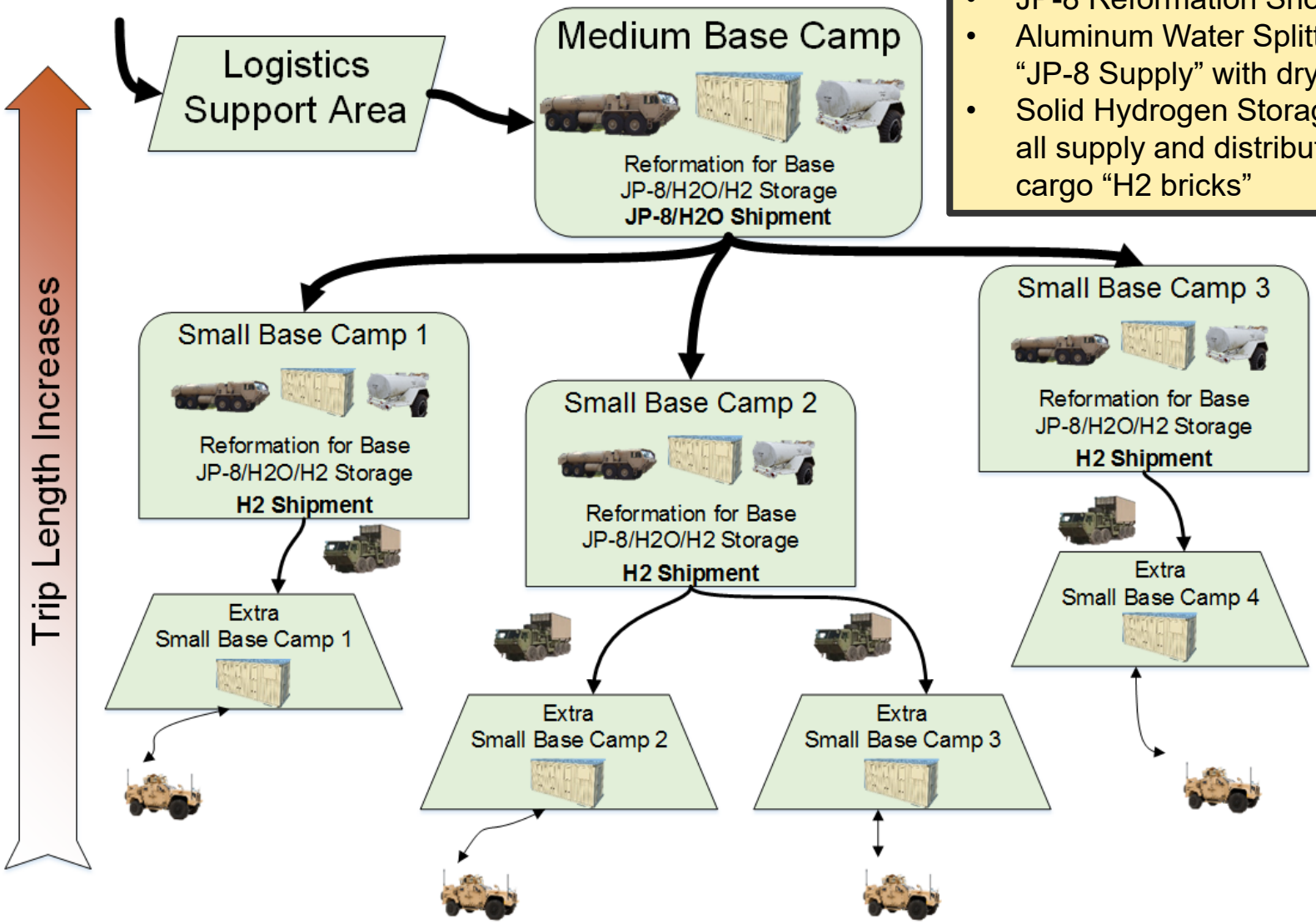
2017-2018 Major Task:

"When does current fuel cell technology make sense for the Army?"

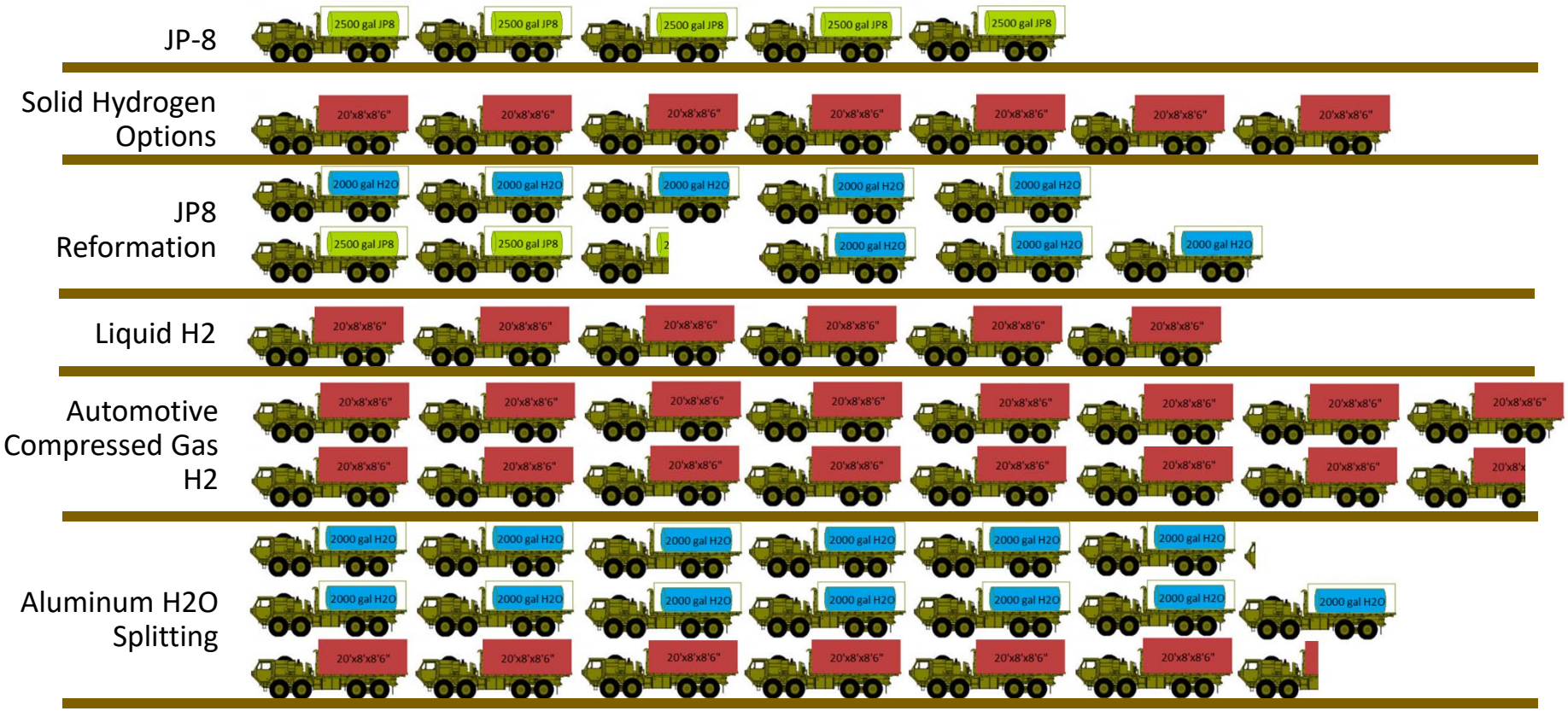
- GVSC electrification strategy → is this an enabling technology?
- Analyzed "conversion" of a brigade to hydrogen fuel cells
  - 10 days scenario
  - Hydrogen sourced from:
    - JP-8 Reformation
    - Aluminum Water Splitting
    - Solid Hydrogen Media (e.g. Alane)
  - Vehicles converted:
    - "Light" trucks and generators
    - All trucks, generators

MOTORIZED INFANTRY IN STABILITY OPS OVERVIEW

- JP-8 Reformation Shown
- Aluminum Water Splitting replaces "JP-8 Supply" with dry cargo
- Solid Hydrogen Storage replaces all supply and distribution with dry cargo "H2 bricks"



HYDROGEN GENERATION OPTIONS ON A LARGE SCALE



M1120 LHS Capacities, no trailers. Corrected for improved fuel consumer efficiency and H2 to JP-8 energy difference.
Compression of H2 and fuel consumed by M1120 ignored.

GVSC HYDROGEN STORAGE PATHWAYS

- Gaseous H2 Storage
  - Remains a focus due to availability; automotive standard
  - Used for demonstrators
  - Conformable storage technology of interest
- Cryo-compressed H2 storage
  - Work initiated in 2018 with Argonne National Lab
  - Near-term method to achieve minimal acceptable range
- Onboard Reformation and Water Splitting
  - Generally not believed to be viable across Army fleet
  - Specialty applications or stationary H2 generation only
- Solid H2 Storage, long-term interest
  - Primary storage
    - Cargo flexibility and minimal logistics equipment
    - Relatively safer than JP-8 or H2
  - Secondary storage
    - High storage density
    - Conformable
    - Non-cryogenic

CURRENT HYDROGEN GENERATION, DISTRIBUTION, STORAGE, AND DEMONSTRATION

1st Prototype Commercial Fuel Cell Tactical Vehicle

- Obtain soldier feedback within an operational context demonstrating the capabilities of a hydrogen fuel cell powered vehicle
- Use Data and Soldier feedback to shape follow-on fuel cell vehicle efforts

1st Prototype JP-8 Reformer

- 18-30 kg H2 per day
- Skid mounted, forklift, 600 lbs
- Low power requirement during operation (~600W)
- Scalable system design

1st Prototype Tactical Hydrogen Operational Refueler (THOR)

- SAE J2601 700 bar T20 fueling
- Contained within a 20 foot ISO shipping container that can be handled by existing Army trucks
- 54 kg of DOT approved hydrogen storage

FUTURE HYDROGEN GENERATION, DISTRIBUTION, STORAGE AND DEMONSTRATION

Infrastructure

- 2nd Prototype Tactical Hydrogen Operational Refueler (THOR), part of H2 Ecosystem
- Hydrogen Transportation and Distribution Trailer, part of H2 Ecosystem
- Investment in multiple hydrogen generation and storage methods to create system flexibility

Vehicles

- 2nd Prototype Robust Commercial Fuel Cell Tactical Vehicle, part of H2 Ecosystem
    - Hydrogen storage (~10kg) on-board for over 300 miles off-road range
    - Payload capacity for mission equipment and storage plus soldiers
    - Meeting military requirements with all electric powertrain
    - Expanding the number of assets in a field exercise/demonstration
- Multi-Fuel Cell Power System to support larger applications

SUMMARY

GVSC's Fuel Cell Technologies team must address a wide range of applications and their support.

Army applications need more onboard storage and more flexible support systems than commercial systems.

High gravimetric and volumetric solutions are a necessity due to maintaining vehicle capabilities, limited available space, logistics burden.

GVSC believes a multi-prong approach is required as H2 storage matures.

THANK YOU

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